

# REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) A team of faculty at the Penn State Rotorcraft Center of Excellence has integrated five new facilities into a broad range of research and educational programs focused on rotorcraft noise and vibration control. The new facilities are: (1) Airframe-Driveshaft Active Control Testbed, (2) Real-Time Visualization and Computation Facility, (3) High Frequency Elastomeric Material and Component Characterization Test Facility, (4) Scanning Laser Vibrometer for Rotorcraft Noise and Vibration Control, and (5) Scale Model Helicopter Fuselage Vibration test Facility. These new facilities have significantly improved the ability of Penn State graduate students and faculty to contribute to DoD sponsored research programs in the field of Rotorcraft Engineering. Each item is linked directly to existing multi-year programs at Penn State including the ARO sponsored MURI on Active Control of Rotorcraft Noise and Vibration, the NRTC Rotorcraft Center of Excellence, ARO Young Investigator Awards, ARO, ONR, and NASA Core Program Grants, and numerous coordinated contracts with industry. This experimental equipment has allowed for new data and measurements in the areas of rotorcraft vibration and noise control, low vibration dynamic systems, enhanced safety and reliability, and advanced composite materials. In addition, new specialized computational facilities will be focused on an array of numerically intensive rotorcraft optimization projects, aeroacoustic prediction methods, and aeroelastic simulations. This equipment has had a major positive impact on the educational infrastructure and resources at the recently established Penn State Rotorcraft Center of Excellence.			
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# **FINAL GRANT REPORT: DURIP 38222-EG-RIP**

## **Experimental and Computational Instrumentation for Rotorcraft Noise and Vibration Control Research at the Penn State Rotorcraft Center**

**Edward C. Smith  
Aerospace Engineering Department  
Penn State University  
Rotorcraft Center of Excellence**

**June 22, 2001**

### **ABSTRACT**

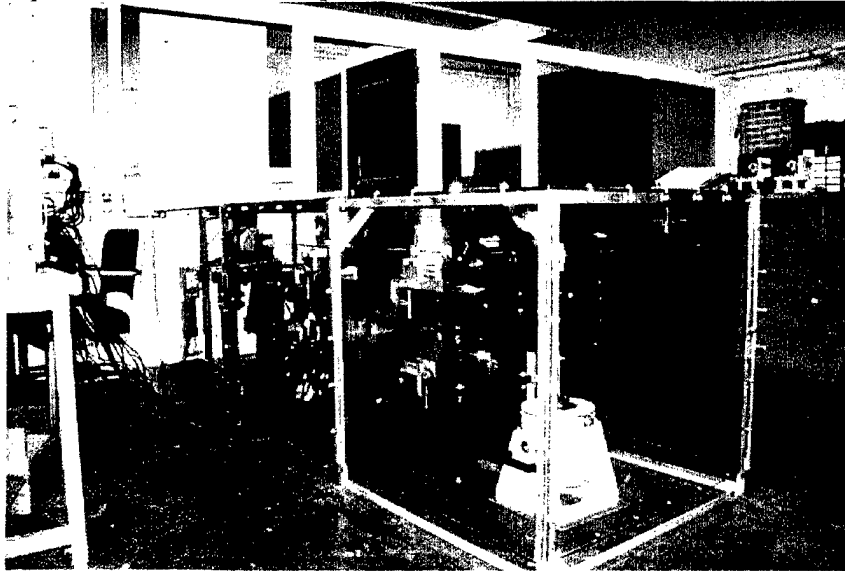
A team of faculty at the Penn State Rotorcraft Center of Excellence has integrated five new facilities into a broad range of research and educational programs focused on rotorcraft noise and vibration control. The new facilities are: (1) Airframe-Driveshaft Active Control Testbed, (2) Real-Time Visualization and Computation Facility, (3) High Frequency Elastomeric Material and Component Characterization Test Facility, (4) Scanning Laser Vibrometer for Rotorcraft Noise and Vibration Control, and (5) Scale Model Helicopter Fuselage Vibration test Facility. These new facilities have significantly improved the ability of Penn State graduate students and faculty to contribute to DoD sponsored research programs in the field of Rotorcraft Engineering. Each item is linked directly to existing multi-year programs at Penn State including the ARO sponsored MURI on Active Control of Rotorcraft Noise and Vibration, the NRTC Rotorcraft Center of Excellence, ARO Young Investigator Awards, ARO, ONR, and NASA Core Program Grants, and numerous coordinated contracts with industry. This experimental equipment has allowed for new data and measurements in the areas of rotorcraft vibration and noise control, low vibration dynamic systems, enhanced safety and reliability, and advanced composite materials. In addition, new specialized computational facilities will be focused on an array of numerically intensive rotorcraft optimization projects, aeroacoustic prediction methods, and aeroelastic simulations. This equipment has had a major positive impact on the educational infrastructure and resources at the recently established Penn State Rotorcraft Center of Excellence.

### **DURIP Facility Descriptions**

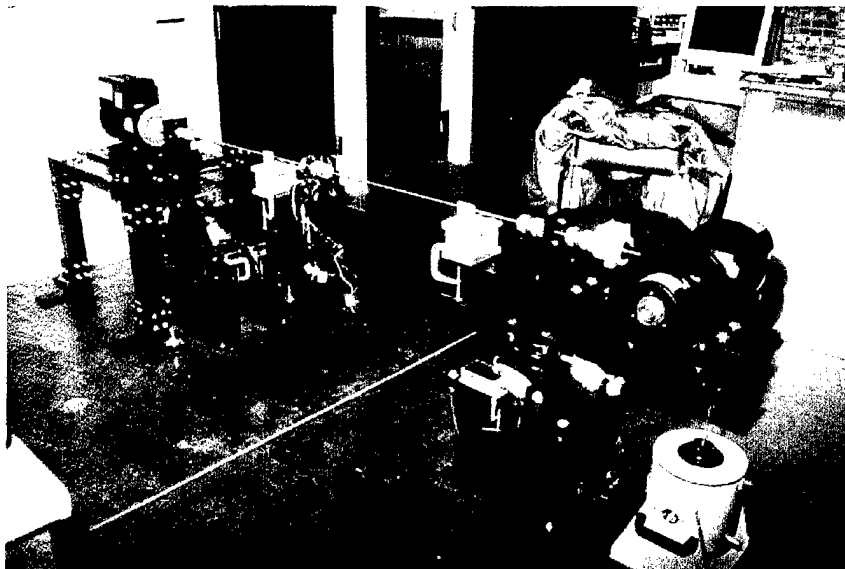
#### **Item (1) Airframe-Driveshaft Active Control Testbed**

A unique, custom-designed facility has been developed for testing of scale model helicopter driveline dynamics. The facility, depicted in the figures below, features segmented shafting connected by flexible couplings. The base structure is flexible to represent primary bending modes of the tailboom or wing structure. Static misalignment or dynamic forcing of the base structure can be prescribed. Shafting is supported by either active magnetic bearings or conventional hanger bearings. Both subcritical and supercritical drivelines can be accommodated. A set of magnetic brakes is designed to load the shaft in

torsion and a precision motor controls the driving shaft speed. Instrumentation includes optical probes, force transducers, torque sensors, and shaft speed sensors.

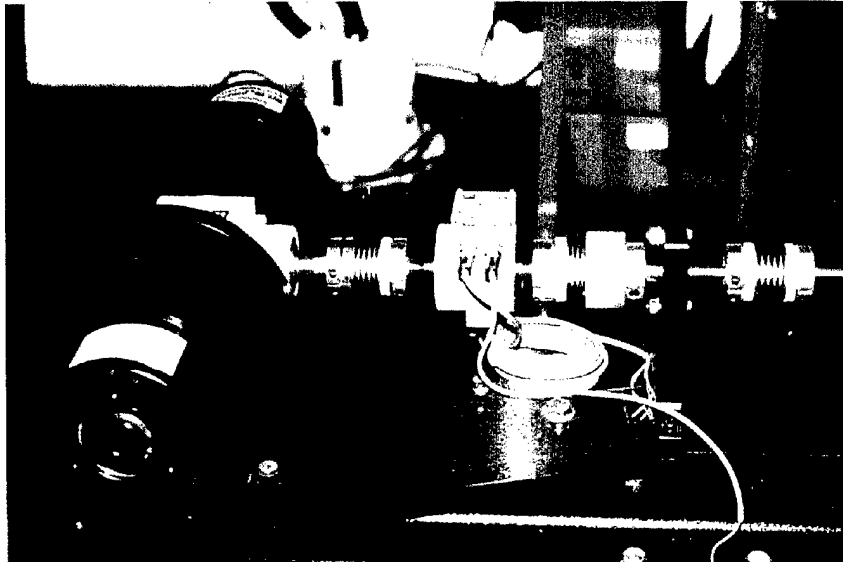


**Penn-State Super-Critical AMB Teststand**

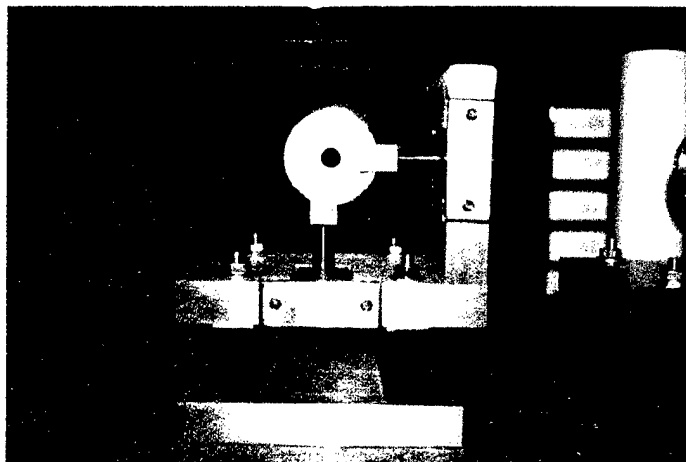


**Driveline, Left to Right:**  
**Motor, Segmented Supercritical Driveshafts, Shaft End-Load Assembly**

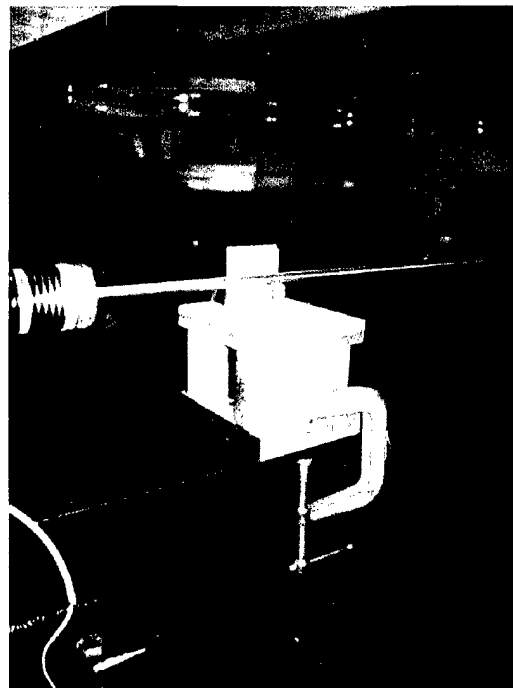
**Foundation, Left to Right:**  
**Pin-Joint, Flexible Foundation I-Beam, Foundation Spring, Shaker**



**End-Load Assembly: (Torque Sensor, Gearbox, Flywheels & Brakes)**  
**Simulates Torsional Inertia and Static Load Torque Conditions.**  
**Note: Assembly is mounted on a misalignable base-plate to simulate various amounts of angular misalignment**



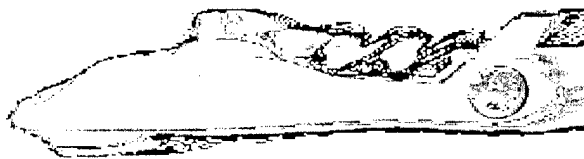
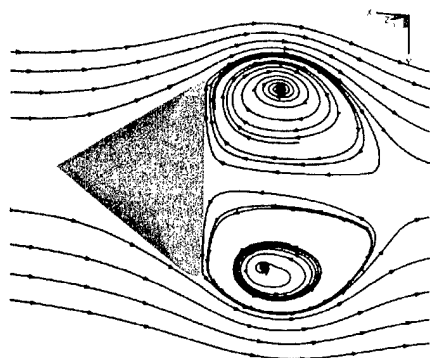
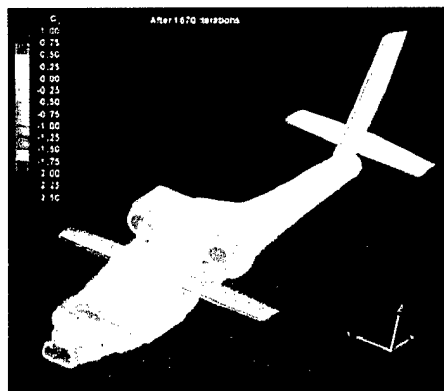
**Shaft Damper Assembly: 1 of 2**  
**(Damper Clamp Fixture, Two Viscous Piston Dampers, Damper Bearing-Ring and Sliders)**



**3/8 inch Dia Driveshaft, Horizontal and Vertical Fiber Optic Displacement Sensors & Fixture Mounted on Foundation Beam.**

## Item (2) Real-Time Visualization and Computation Facility

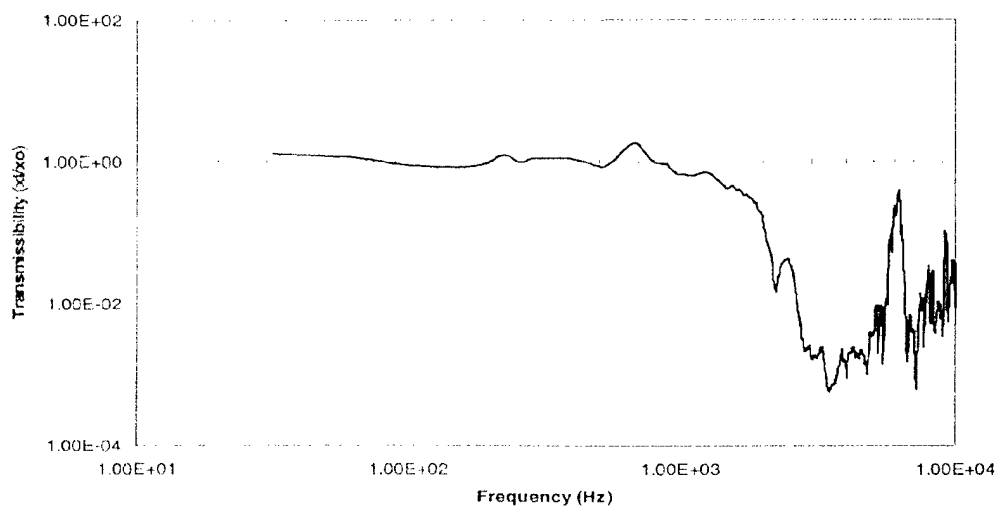
A dual processor SGI Workstation and two dual processor Dell workstations were purchased. Both of these facilities have been used for RCOE graphics, visualization, CAD, and CFD grid generation. The figures below illustrate some of the typical flow simulation visualization that has employed the new facilities at Penn State.



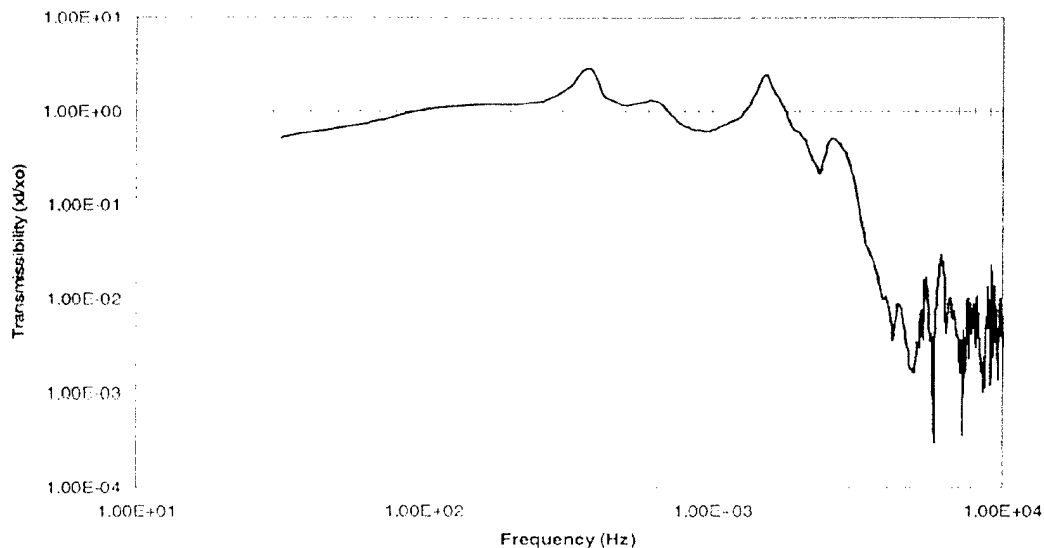
### Item (3) Elastomeric Material and Component Characterization Test Facility

A high frequency vibration test and material characterization test facility was developed at Penn State. This facility consists of high capacity electrodynamic shakers, signal analyzers, and amplifiers. Using this new facility, several different types of vibration isolation mounts can be evaluated by our students. Some typical transmissibility data is presented in the Figures below.

**Figure 2: Experimental Transmissibility of Mount 1 - Swept Sine Input**  
(0 - 12.8 kHz) - 200 Vrms Averages



**Figure 3: Experimental Transmissibility of Mount 2 - Swept Sine Input**  
(0 - 12.8 kHz) - 200 Vrms Averages

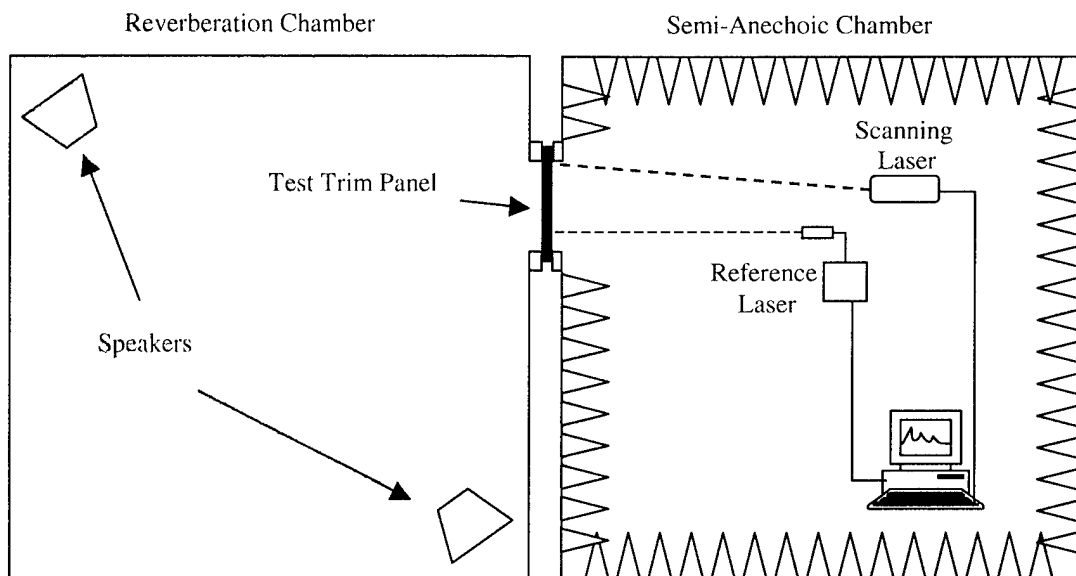


#### Item (4) Scanning Laser Vibrometer for Rotorcraft Noise and Vibration Control

Rapid, automated vibration measurement and analysis are possible with the laser Doppler vibrometer in conjunction with a fast scanning system, FFT processing and video graphics. The scanning laser vibrometer is applicable to a wide variety of vibration measurements and offers many advantages over more traditional experimental methods such as accelerometers. For example, there is no added mass or local stiffness and therefore, no modification of the measured structural response. The experimental setup is faster and less complicated since there are no transducers to attach, calibrate or reposition. Calibration and mounting errors are therefore eliminated. Non-contacting, full-field measurements with high spatial resolution are possible to test small delicate objects. The wide frequency and dynamic range and accuracy allow for vibration measurement under previously impossible operating conditions. Finally, the video animations provide a graphic interface tool to readily examine complex modes of vibration as well as operating or dominant frequency vibration patterns.

In the Penn State Rotocraft Center, the capabilities of the PolyTec scanning laser vibrometer are widely utilized. Through use of the broad frequency range, spatial resolution, and large scanning area capabilities of the vibrometer, surface velocity measurements are used to calculate radiated sound power from a structure. The calculated radiated sound power does not contain secondary noise sources that would be apparent in traditional acoustic measurements. The effects of structural modifications on vibration patterns and radiated sound power in a transmission loss suite are ascertained through laser vibrometer scans. Overall, both the structural and acoustic applications of the various capabilities of the scanning laser vibrometer are continually broadening in the Penn State Rotocraft Center through various projects:

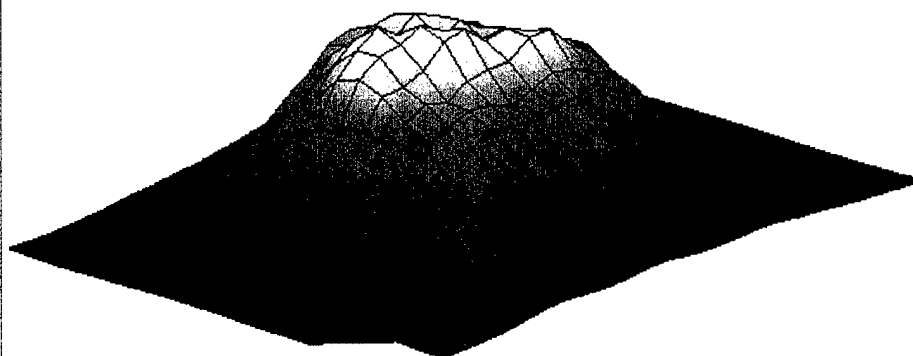
- Transmission loss measurement of helicopter trim panels
- Transmission loss improvements through passive broadband vibration absorber application to trim panels
- Active vibration control of trim panels
- Transmitted sound power reduction through application of smart materials to trim panels



**Trim Panel Transmission Loss Test Facility at Penn State**

Domain: FFT  
Sig.: Velocity B  
Inst. Val.

mm/s



Band 3	91.25 Hz
Angle	20 °

Surface velocities of Bell 430 Transmission Cover (measured at Penn State using Scanning Laser Vibrometer)

##### **(5) Scale Model Helicopter Fuselage Vibration test Facility**

A unique new test facility to assess active vibration control strategies has been developed. The facility consists of a dynamically scaled helicopter tailboom, driven by a vibration shaker to simulate tail buffet loadings. Actuation devices based on piezoceramic stack are used to reduce vibration of the tailboom structure. The tailboom is fabricated using semi-monocoque stiffened skin construction and is instrumented with an array of both strain gages and accelerometers.

